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Revitalizing Traditional Astronomical Instruments: Developing a Local Dial Model for Accurate Prayer Time Determination

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Abstract

This study addresses the limitations of contemporary prayer time instruments, which often require complex calculations, electricity, internet connectivity, or direct exposure to sunlight, by developing a practical, local dial–based tool for community use. Employing a Research and Development (R&D) approach, data were collected through observation and documentation and analyzed using descriptive and comparative methods. The device integrates calculations from the Indonesian Ministry of Religious Affairs, including altitude corrections for *Maghrib*, *Isha*, and *Fajr*, processed through VBA in Microsoft Excel using astronomical formulas from Jean Meeus's Astronomical Algorithms. The instrument comprises a dial field, support field, tripod, thread, spirit level, minute-scale ruler, and stick, with the dial incorporating an analog prayer-time circle, an *'Asr* curve, and a *Zuhr* line. Comparative testing against the official prayer schedule demonstrates high accuracy with only a one-minute deviation. Designed for long-term use, the device remains valid for 50 years from 2023 and is applicable within a 27.5 km radius of Universitas Muhammadiyah Makassar.

Keywords: local dial instrument; prayer time; solar position; altitude correction

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Penelitian ini mengatasi keterbatasan instrumen penentu waktu salat modern yang kerap membutuhkan perhitungan kompleks, listrik, koneksi internet, atau paparan sinar matahari langsung, dengan mengembangkan alat praktis berbasis dial lokal yang mudah digunakan masyarakat. Penelitian ini menggunakan pendekatan Research and Development (R&D), dengan pengumpulan data melalui observasi, dan dokumentasi, serta analisis deskriptif dan komparatif. Perancangan alat mengintegrasikan perhitungan Kementerian Agama Republik Indonesia, termasuk koreksi ketinggian untuk waktu Magrib, Isya, dan Subuh, yang diolah melalui VBA pada Microsoft Excel menggunakan rumus astronomi dari Astronomical Algorithms karya Jean Meeus. Alat ini terdiri atas bidang dial, bidang penyangga, tripod, benang, waterpass, penggaris skala menit, dan tongkat, dengan komponen dial berupa lingkaran analog waktu salat, kurva Asar, dan garis Zuhur. Hasil pengujian yang dibandingkan dengan jadwal resmi waktu salat menunjukkan tingkat akurasi tinggi dengan selisih hanya satu menit. Alat ini dirancang untuk penggunaan jangka panjang selama 50 tahun sejak 2023 dan dapat diterapkan dalam radius 27,5 km dari Universitas Muhammadiyah Makassar.

Kata Kunci: instrumen dial lokal; waktu salat; posisi Matahari; koreksi ketinggian

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A. Introduction

Prayer (*ṣalāh*) in Islam is a strictly time-bound act of worship, and its validity is inseparable from adherence to its prescribed times. Surah *al-Nisā'* (4:103) emphasizes that performing prayer outside its designated period renders it invalid. While the Qur'an does not provide detailed boundaries for each prayer time, the Hadith of the Prophet Muhammad offers precise indicators for determining the times.[1] For instance, the time of *Ẓuhr* begins after the sun passes its zenith, *'Aṣr* commences when an object's shadow equals its length, Maghrib begins at sunset, *'Ishā'* starts with the disappearance of the red twilight, and *Fajr* extends from the appearance of true dawn until sunrise.[2] These textual descriptions highlight that the movement of the sun serves as the primary natural reference for determining the beginning of each prayer.[3]

Because prayer times depend directly on solar altitude and its daily apparent motion, contemporary Islamic astronomy applies two main approaches: *hisāb* (calculation) and *ru'yah* (direct observation). Calculation involves employing astronomical algorithms, often using ephemeris data and coordinate-based formulas, while *ru'yah* relies on observing solar shadows, twilight, and dawn phenomena.[4] In practice, various tools have been developed, such as digital prayer timetables, perpetual calendars,[5] and ephemeris-based computational methods. Digital systems using Arduino.[6] Other microcontrollers offer user-friendly access to prayer times, particularly in mosques. However, these devices depend on electricity, stable internet connectivity, and modern hardware, factors that may not be available in remote or underdeveloped regions.[7]

Alongside digital systems, classical astronomical instruments such as the *istiwā'* stick,[8] astrolabe, sundial, *bencet*,[9] and *rubu' mujayyab* remain valuable for determining prayer times using the shadow of the sun.[10] Contemporary scholars have also developed innovative sunlight-based tools such as al-*Murabba'*[11] and *Mizwala*.[12] Additionally, web-based prayer time generators (e.g., LP2IF-RHI by Mutoha Arkanuddin) have expanded access to accurate schedules across Indonesia.[13] Nevertheless, these tools continue to share certain limitations: they require sunlight, involve manual interpretation, depend on technological infrastructure, or employ Arabic scripts that are not easily

[1] Ahmad Sarwat, *Ensiklopedia Fikih Indonesia 3: Shalat* (Jakarta: Gramedia Pustaka Utama, 2019).

[2] Ahmad Izzuddin, *Ilmu Falak Praktis* (Semarang: Pustaka Rizki Putra, 2017).

[3] Bilal Irfan and Aneela Yaqoob, "Between Fajr and Isha: Understanding Sleep Dynamics in Islamic Prayer Timings and Astronomical Considerations," *Cureus*, April 24, 2024, https://doi.org/10.7759/cureus.58911.

[4] Irfan and Yaqoob.

[5] Moch Riza Fahmi, "Study Komparasi Jadwal Salat Sepanjang Masa H. Abdurrani Mahmud Dengan Hisab Kontemporer," *Jurnal Bimas Islam* 10 (2017): 565–90.

[6] Emil Naf'an, "Akurasi Sistem Penjadwalan Sholat Digital Menggunakan Arduino Sebagai Pengendali," *Jurnal Sistim Informasi Dan Teknologi* 1, no. 4 (2019): 81–88, https://doi.org/https://doi.org/10.35134/jsisfotek.v1i4.13.

[7] Fahmi, "Study Komparasi Jadwal Salat Sepanjang Masa H. Abdurrani Mahmud Dengan Hisab Kontemporer."

[8] Muhyiddin Khazin, *Kamus Ilmu Falak* (Yogyakarta: Buana Pustaka, 2005).

[9] Siti Tatmainul Qulub, *Ilmu Falak Dari Sejarah Ke Teori Dan Aplikasi* (Jakarta: Rajawali Pers, 2017).

[10] Muhyiddin Khazin, *Ilmu Falak Dalam Teori Dan Praktik* (Yogyakarta: Buana Pustaka, 2004).

[11] M. Ihtirozun Ni'am, *Al-Murobba': Inovasi Alat Falak Multifungsi* (Semarang: Mutiara Aksara, 2020).

[12] Faizatuz Zulfa, "Uji Akurasi Mizun (Mizwala-Sundial) Dalam Penentuan Awal Waktu Salat Zuhur Dan Asar" (Universitas Islam Negeri Walisongo Semarang, 2020).

[13] Mutoha Arkanuddin, "Jadwal Shalat," Rukyatul Hilal Indonesia, 2018, https://rukyatulhilal.org/jadwalshalat/.

understood by the general public.[14] Calendar-based schedules also carry issues of inconsistency, lack of citation, and the absence of *ikhtiyāt* (precautionary margins), necessitating further verification of their accuracy.

Field observations indicate that many regions, such as remote islands, mountainous areas, and isolated rural communities, still lack reliable access to electricity, internet services, or modern devices. In such contexts, communities often revert to manually observing solar phenomena, which can result in delays or inaccuracies when performing prayers.[15] These circumstances reveal the need for an instrument that is simple, independent of digital infrastructure, practical for non-experts, and adaptable to diverse geographical settings. An accessible analog device would support users in determining prayer times accurately without requiring advanced calculation skills or continuous sunlight exposure.

A consistent feature of traditional sunlight-based instruments is the use of a stick (gnomon) and dial plane, elements that inherently limit their operation to daytime sunlight and restrict functionality primarily to the *Ẓuhr* and *'Aṣr* prayers. Additionally, many still require manual calculations.[16] Meanwhile, recent studies on astronomical instruments underscore the ongoing relevance and potential for innovation in analog devices. Maslikov (2021) provides an in-depth analysis of a rediscovered Greek portable sundial, demonstrating how ancient analog systems incorporated complex calendrical and latitude-based mechanisms.[17] Similarly, Talbert (2017) and Field (1990) document Roman and Byzantine portable sundials as sophisticated tools capable of timekeeping across regions.[18] These studies highlight that well-designed analog instruments can achieve substantial precision. Building on this body of research, the present study aims to develop a local dial model capable of determining all prayer times with improved accessibility, regional adaptability, and enhanced accuracy through altitude-corrected modifications.

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B. Method

This study employed a Research and Development (R&D) design aimed at producing a functional instrument for determining Islamic prayer times and evaluating its accuracy. Data sources consisted of both primary and secondary materials. Primary data were obtained through field observations and interviews, while secondary data included books, journal articles, official documents, and online resources related to Islamic astronomy and prayer time calculation. The development process followed three systematic stages. *First*, the researcher conducted an initial needs assessment by reviewing existing sunlight-based instruments, such as sundials, *istiwā'* sticks,

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[14] Nurul Kausar Nizam et al., "The Concept Of Zoning System For The Determination Of Prayer Time In Malaysia From Contemporary Islamic Jurisprudence Perspectives," *Al-Qanatir: International Journal of Islamic Studies* 28, no. 2 (2022): 168–77.

[15] Safiq Rosad, Anton Yudhana, and Abdul Fadlil, "Jadwal Sholat Digital Menggunakan Metode Ephemeris Berdasarkan Titik Koordinat Smartphone," *IT JOURNAL RESEARCH AND DEVELOPMENT* 3, no. 2 (January 17, 2019): 30–43, https://doi.org/10.25299/itjrd.2019.vol3(2).2285.

[16] Mohd Hafiz Safiai et al., "Diversity of Time Zones at Burj Khalifa in Performing Prayer and Fasting in Skyscrapers," *International Journal of Advanced Research (IJAR)* 11, no. 01 (2022): 1808–12, https://doi.org/https://doi.org/10.21474/IJAR01/16210.

[17] Sergei J. Maslikov, "The Greek Portable Sundial from Memphis Rediscovered," *Journal for the History of Astronomy* 52, no. 3 (2021): 311–24, https://doi.org/https://doi.org/10.1177/002182862110330.

[18] Lars Gislén, "Four Instruments In Martín Cortés' Breve Compendio De La Sphera And A Rule For Finding The Age Of The Moon," *Journal of Astronomical History and Heritage* 27, no. 1 (2024): 53–62.

and contemporary innovations, and identifying design principles relevant to prayer time determination. *Second*, prayer time calculations (*ḥisāb*) were performed using parameters including geographical coordinates, local time, the equation of time, solar declination, atmospheric refraction, horizon altitude, site elevation, and precautionary margins (*ikhtiyāt*). These calculations served as the basis for designing a dial instrument consisting of a 360° circle, an analog time ring, and an *'Aṣr* shadow curve. The design was created using Affinity Designer software and fabricated through laser cutting. Third, the prototype underwent accuracy testing by comparing the calculated prayer times with the official schedule of the Ministry of Religious Affairs and by evaluating the instrument's performance through direct solar shadow observations.

Data collection employed three techniques. Observation involved directly monitoring solar shadow movement to determine prayer times using both the researcher-developed instrument and the Ministry's official schedule as a reference standard. Interviews were conducted with an Islamic astronomy lecturer at Universitas Muhammadiyah Makassar, representing the target user group, to gather expert feedback on usability and design refinement. Documentation was undertaken to collect supporting materials, including field notes, photographs, regulatory references, and other relevant records. The analysis utilized a comparative approach, in which observational results obtained from the developed instrument were systematically compared with reference values. Discrepancies between the two measurements were interpreted as indicators of the instrument's accuracy and reliability.

C. Result and Discussion

1. Instrument Design, Computational Framework, and Functional Development of the *Shollu* Local Dial

The instrument developed in this study is named the *Shollu* Dial Local, a combination of the words *Shollu* (a command to pray), dial (referring to a circular plane), and Local (indicating that the tool is designed for region-specific application). The device integrates three key functional components: the analog prayer time circle, the meridian line indicating the onset of *Zuhr*, and the '*Asr* shadow-length curve. Structurally, the instrument features a circular dial mounted on a square supporting base. The prayer time indicators were calculated to ensure long-term usability, and initial coordinates from Universitas Muhammadiyah Makassar were used as the reference site for prototype construction. For use in another region, a new dial must be produced to accommodate local astronomical parameters.

The development process began with calculating two essential astronomical variables: solar declination and the equation of time, which change continuously throughout the year and directly influence the accuracy of prayer times. Prayer time calculations were then performed using the criteria of the *Indonesian Ministry of Religious Affairs*, supplemented with altitude corrections for *Maghrib*, *Isha*, and *Fajr*. This adjustment is necessary because varying horizon profiles across different locations affect the observable moments of sunset, twilight, and dawn. Once the calculations were completed, the results were translated into visual components of the device, namely the analog prayer time circle, the *Zuhr* meridian line, and the '*Asr* shadow curve. The design process was carried out using Affinity Designer software, after which the dial was engraved using acrylic material via laser cutting. When fully assembled, the Shollu Dial Local consists of a dial plane, gnomon, tripod, supporting base, ruler, and spirit level. This configuration enables users to view prayer times through a combination of shadow observation and analog time indicators, eliminating the need for electricity or internet access.

Accuracy testing was conducted after all components were assembled. The calculated prayer times displayed on the dial were compared with the official prayer schedule issued by the Directorate of Islamic Guidance of the Ministry of Religious Affairs. The evaluation focused on three key features of the device: the analog prayer time circle, the *Zuhr* meridian line, and the *'Asr* shadow curve. Since prayer times vary significantly across geographical regions, the initial testing used the coordinate data of Universitas Muhammadiyah Makassar retrieved from Google Earth with 119°26'27.65" E longitude, 5°10'55.14" S latitude, local time (GMT+8), and 5m MASL.

Figure 1. Instrument Design

To streamline the complex astronomical computations required during development, the researcher employed Microsoft Excel with VBA programming. Functions were created to automate repetitive calculations and manage variables such as solar altitude, atmospheric refraction, and time conversion. This computational support facilitated consistent replication of the formulas used to generate the analog prayer time circle and the shadow curves. The analog circle itself was constructed by plotting the daily onset of each prayer time in a circular format, enabling users to determine prayer times by aligning a minute-scale ruler with the corresponding date on the device. This intuitive reading technique eliminates the need for numerical calculations. Validation using an example date (August 28, 2023) demonstrated close agreement with the official timetable of the Ministry of Religious Affairs.

The development of the *'Asr* shadow curve required additional steps beyond those used for the analog circle. Specifically, the researcher calculated the dates of *Istiwā' A'dham* when an object casts no shadow at noon as well as the sun's northernmost and southernmost declination points, both of which significantly influence seasonal variations in shadow length. These parameters were used to determine reference shadow lengths throughout the year, which were then plotted to form the *'Asr* curve. The resulting curve enables users to identify the onset of *'Asr* prayer based on the measured shadow of a gnomon, accommodating differences in juristic interpretation within the *Shāfiʿī* and *Ḥanafī* schools regarding the required shadow length.

These juristic considerations formed an integral part of constructing the final ʻ*Asr* shadow curve. According to the *Ḥanafī* school, ʻ*Asr* begins when an object's shadow reaches twice its height, whereas the *Shāfiʿī* school states that ʻ*Asr* starts when the shadow equals the object's height. Hadith evidence narrated by *Jābir ibn ʿAbdillāh* further illustrates both conditions by showing that the Gabriel invited the Prophet Muhammad to perform ʻ*Asr* at each of these shadow lengths on two successive days. Additional views, such as Mālik's categorization of the end of *Zuhr* as a musytarak (shared) period, support the need for a flexible, observation-based approach.[19] Incorporating these perspectives, the researcher constructed the ʻ*Asr* curve using previously calculated parameters, *Istiwāʻ A'dham*, seasonal solar positions, gnomon shadow lengths, and azimuthal variations, ensuring that the *Shollu* Dial Local accurately reflects both astronomical phenomena and juristic diversity.

2. Performance Assessment of the Local Dial Instrument for Prayer Time Determination

The accuracy of the *Shollu* Dial Local was evaluated through a series of field tests conducted at Universitas Muhammadiyah Makassar. The primary objective of the testing phase was to compare the device's calculated and observed prayer times with the official schedule issued by the Directorate of Islamic Guidance of the Ministry of Religious Affairs. To ensure reliability, the researcher performed repeated measurements over six consecutive days, covering the dates from August 28 to September 2, 2023. Testing began by comparing the analog prayer time circle displayed on the device with the corresponding times in the official schedule. The instrument's dial was used to determine the times of *Fajr*, *Duha*, *Zuhr*, *Asr*, *Maghrib*, and *Isha*. Across the six days of testing, the difference between the device and the Ministry schedule was consistently within one minute for all prayer times. This finding demonstrates that the analog circle component of the device performs with high accuracy and aligns closely with the established national calculation standard.

The accuracy of *Zuhr* time was further examined using the meridian line. By observing the moment when the gnomon's shadow crossed the meridian line, the device indicated *Zuhr* between 12:08 and 12:10. When compared with the official schedule, which listed Zuhr at 12:06–12:07 during the same period, the difference ranged from one to three minutes. This slight discrepancy is consistent with the nature of meridian-based observation, which is sensitive to local horizon conditions and minor variations in latitude and elevation.

The ʻ*Asr* prayer time was assessed using the shadow-length curve. The researcher measured the length of the gnomon's shadow each day, which ranged from 6 to 7 cm depending on the date. These measurements corresponded to ʻ*Asr* times between 15:24 and 15:26. When compared with the Government schedule, which listed ʻAsr between 15:22 and 15:25, the difference also fell within the range of one to three minutes. The slight delay or advancement observed in the device's readings

[19] Tamhid Amri, "Waktu Shalat Perspektif Syar'I," *Asy-Syari'ah* 17, no. 1 (2014), https://doi.org/https://doi.org/10.15575/as.v17i1.640.

reflects the astronomical variations in solar declination and the equation of time, as well as the altitude corrections applied by the researcher.

Table 1: Summary of Accuracy Evaluation of the *Shollu* Dial Local

Component Tested	Reference Standard	Period	Shollu Dial Local	Government Schedule	Difference	Notes
Analog Prayer Time Circle	Government (all prayer times)	August 28 – September 2, 2023	Matches all prayer times with only ±1 minute variance	Listed schedule for Makassar (markaz-based)	0–1 minute	High accuracy; differences due to coordinate precision and altitude corrections.
Zuhr Time (Meridian Line)	Solar meridian transit method	6 days of testing	12:08–12:10	12:06–12:07	1–3 minutes	Minor delays inherent to meridian-line observations; sensitive to local horizon and elevation.
‘Asr Time (Shadow Curve)	Shadow length per juristic criteria	6 days of testing	Asr at 15:24–15:26 with 6–7 cm shadow	15:22–15:25	1–3 minutes	Variation reflects differences in declination, equation of time, and altitude.
Difference Across All Prayer Times	—	6 days	Generally earlier by 1 minute; occasionally later by 1 minute	—	±1 minute	Acceptable astronomical variation.
Long-Term Stability (50-year)	Government calculation trends	2023–2073	Maximum variance: 1 minute	—	1 minute	Device remains stable across long-term ephemeris changes.
Extended Projection (100-year)	Researcher’s VBA-Excel model	2023–2123	Accuracy maintained with an annual difference ≤1 minute	—	≤1 minute/year	Long-term recalibration is still recommended.
Effective Operational Radius	Based on Earth's circumference and the time-longitude ratio	—	Reliable within ±27.5 km E–W of reference site	—	1 minute per 0.1° (~11 km)	Suitable for regional use around Makassar.

Overall, the results demonstrate a high level of agreement between the device and the official schedule. The consistent one-minute difference observed in nearly all prayer times is attributable to factors such as differences in coordinate precision, altitude variations, and the distinct astronomical parameters used in the researcher’s calculations compared to those employed by the Government.

Whereas the Ministry uses a generalized markaz coordinate for Makassar, the *Shollu* Dial Local is calibrated to the precise coordinates of the university campus (5 meters above sea level), which naturally leads to slight, but scientifically acceptable, variations. Long-term verification of the device's accuracy also shows promising results. When projected using the researcher's astronomical calculations for 50 years (2023–2073), the device maintains a maximum difference of only one minute. Even when extended to 100 years (up to 2123), the discrepancy remains within one minute per year. This level of Stability demonstrates that the computational foundation embedded in the device's design is robust and suitable for long-term application.

Based on geographical analysis, the device can be used reliably within a radius of approximately 27.5 km east–west of the reference location while maintaining a one-minute accuracy margin. This calculation is derived from the relationship between Earth's circumference and longitudinal time differences, whereby 1° of longitude corresponds to approximately four minutes, and 0.1° (or roughly 11 km) corresponds to one minute of time difference. Thus, the *Shollu* Dial Local provides reliable regional coverage without compromising precision. In summary, both the calculation-based and observation-based testing confirm that the *Shollu* Dial Local is highly accurate, with discrepancies well within acceptable limits for prayer time determination. These results indicate that the device is suitable for practical use, especially in communities where access to digital tools, electricity, or internet connectivity is limited.

3. Strengths and Limitations of The *Shollu* Local Dial Instrument

The innovation of the *Istiwā'* Stick integrated with an analog prayer time circle represents a noteworthy advancement in Islamic astronomical instrumentation. Compared to many existing tools, ranging from simple sunlight-dependent devices to digital systems that require electricity and stable internet connectivity, the *Shollu* Dial Local offers a practical and low-cost alternative. It eliminates the need for manual computation and remains fully functional regardless of weather conditions. Even under cloudy skies, the analog circle enables users to determine prayer times accurately. At the same time, sunlight-based observations can still be performed using the *'Asr* shadow curve and the meridian line. The instrument is also simple to operate: the user aligns a ruler with the desired date and reads the minute marker where the line intersects the analog circle. Field tests have shown that the device can be operated in under one minute and provides a high level of accuracy, further enhanced by altitude corrections tailored to the user's geographical location.

Table 2: Summary of the *Shollu* Dial Local

Prayer Time	CPI Mosque	Maros Grand Mosque	Pangkep Grand Mosque	Gowa Grand Mosque
Fajr	04.48	04.47	04.47	04.47
Duha	06.26	06.26	06.26	06.26
Zuhr	12.06	12.05	12.05	12.06
Asr	15.23	15.22	15.22	15.23
Maghrib	18.06	18.06	18.05	18.05
Isha	19.14	19.14	19.14	19.14

However, despite these advantages, the instrument cannot overcome all limitations in a single stage of development. It remains a manual tool with a limited regional scope, as a specific dial must be constructed for each locality due to differences in geographical coordinates. The device also requires a clock for time referencing, and its current design is not yet optimized for compactness or portability. From a methodological perspective, the study also highlights the constraints of using longitudinal time-difference conversion between regions. Calculating prayer times solely based on longitude differences does not account for variations in elevation or horizon height, which can alter the observed times of sunrise, sunset, and twilight.

This limitation becomes evident when comparing prayer times calculated from absolute coordinates with those derived from longitude-difference conversion. Using the actual coordinates of major mosques in Makassar, Maros, Pangkep, and Gowa, the real-coordinate method produced differences of up to one minute between locations. Meanwhile, the longitude-difference method generated almost identical results but failed to capture minor yet meaningful variations caused by elevation differences and local horizon conditions. These findings demonstrate that while the *Shollu* Dial Local performs with high accuracy within its designated area, the use of real coordinate data remains the more precise method for determining prayer times, as it incorporates both geographical position and elevation.

In conclusion, the *Shollu* Dial Local functions as an accurate and practical instrument for determining prayer times in regions with limited access to digital technology or electricity. Nevertheless, further refinement is needed to expand its portability and adaptability across broader geographical areas. More importantly, real-coordinate calculations should be prioritized over longitude-difference conversions to ensure that local geographical factors, especially elevation, are appropriately reflected in the resulting prayer times.

4. Jurisprudential Basis of Prayer Times and Its Relevance to Astronomical Instruments

Prayer (*ṣalāh*) occupies a central place in Islamic worship and is legally prescribed for Muslims within clearly defined temporal bounds. Although the *Qur'an* commands the establishment of prayer, it does not enumerate precise numerical limits for each prayer; hence, classical jurists relied on the Prophetic tradition and observable natural phenomena to derive the indicators of prayer entry and exit.[20] Contemporary scholarship that examines the juridical and astronomical nexus supports this approach: fiqh prescriptions for prayer times are interpreted in relation to solar phenomena,[21] such as the sun's transit (*zawāl*), shadow lengths, sunset, the disappearance of the red twilight, and the appearance of true dawn.[22]

According to the traditional juristic framework, Zuhr begins at *zawāl*, the sun's passage of the meridian and its subsequent westward decline; '*Asr* starts when an object's shadow attains a juristically relevant length (variously interpreted across schools); Maghrib begins at the setting of the sun's disk; Isha starts after the red twilight (*syafaq al-aḥmar*) has disappeared; and Fajr begins with the appearance of the true dawn (*fajr ṣādiq*). These classical markers have served as reference

[20] Syeikh Abdurrahman Al-Jaziri, *Kitab Shalat Fikih Empat Mazhab* (Bandung: Mizan, 2005).

[21] Ahmad Sarwat, *Waktu Shalat*, ed. Fatih (Jakarta Selatan: Rumah Fiqih Publishing, 2018).

[22] Muhammad Saleh Sofyan, "Tinjauan Astronomis Terhadap Dasar Hukum Penentuan Waktu Asar Mazhab Hanafī" (Universitas Islam Negeri Walisongo Semarang, 2017).

points for both manual observation and calculative (*ḥisāb*) methods that were subsequently developed.[23] Modern attempts to operationalize these juristic indicators have taken two complementary forms: observation-based instruments (e.g., sundials, *istiwā'* sticks, portable dials) and algorithmic *ḥisāb* that implements astronomical formulas. Historical and recent instrument studies, ranging from analyses of portable sundials to reconstructions of universal and region-specific dials, demonstrate that analog devices can embody complex calendrical and latitude-dependent mechanisms, and remain relevant for translating fiqh indicators into practice. The rediscovery and study of portable sundials and universal dials underscore how analog designs can be engineered to meet juridical criteria while remaining independent of electrical infrastructure.[24]

A key technical issue in aligning jurisprudence and instrumentation is the treatment of atmospheric and topographic factors, most notably altitude, refraction, and the sun's semi-diameter, which affect the apparent times of sunrise, sunset, and twilight. Recent engineering and applied astronomy studies have recommended and implemented altitude corrections and refraction adjustments in prayer-time algorithms to improve local accuracy; such corrections are significant when the aim is to meet juristic precision for dawn and twilight thresholds. Incorporating these corrections into device design, therefore, both improves empirical alignment with observable phenomena and better respects juristic intent.[25]

Finally, research comparing digital or web-based prayer schedules and traditional or localized methods highlights an essential practical tension: while online applications and centralized schedules offer convenience and broad coverage, their accuracy may vary by source, and they often rely on generalized coordinates or unspecified parameter choices. Empirical studies of online prayer-time tools warrant caution and local verification, especially in regions with variable elevation or horizon profiles. This underscores the value of a hybrid approach (algorithmically informed but locally calibrated analog instruments), such as the *Shollu* Dial Local, which translates juristic criteria into a tangible instrument while incorporating altitude and coordinate corrections to reflect local fiqh requirements and observational realities better.

D. Conclusion

The design and development of the *Shollu* Dial Lokal (SDL) successfully produced a practical instrument for determining Islamic prayer times based on a local dial system. The device integrates several functional components, including a dial plate, supporting base, tripod, string, spirit level, minute-scale ruler, and gnomon, while projecting prayer times through three key features on the dial surface: the analog prayer time circle, the '*Asr* shadow curve, and the *Zuhr* meridian line. Prayer time calculations were conducted using the geographical coordinates of Universitas

[23] Silvia Andriani Bahri and Sarma Hasibuan, "Muslim Prayer Times on Astronomy and Fuqaha," *Al-Hisab: Journal of Islamic Astronomy* 1, no. 4 (2024): 163–73, https://doi.org/https://doi.org/10.33096/jah.v1i4.21428.

[24] David A. King and François Charette, "A Universal Sundial Made for Sultan Mehmet II, in the Context of Astronomical Instrumentation in Late-15th Century Istanbul," *Suhayl International Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* 21 (2024): 7–208, https://doi.org/10.1344/SUHAYL2024.21.1.

[25] Muhammad Jamaluddin, "Development of Astro Time Islamic Prayer Schedule Application and Altitude Correction Test," *Al-Hilal: Journal of Islamic Astronomy* 4, no. 2 (2023): 133–52, https://doi.org/https://doi.org/10.21580/al-hilal.2022.4.2.12330.

Muhammadiyah Makassar and computed through VBA-based algorithms derived from Jean Meeus's Astronomical Algorithms.

Testing results demonstrate that the SDL achieves a high level of accuracy, with a maximum deviation of approximately one minute when compared with the official prayer schedule issued by the Ministry of Religious Affairs. Measurement trials over multiple days confirmed the device's reliability in both analog reading and shadow-based observations. The instrument is capable of long-term applicability for up to 50 years, starting from 2023, and can be accurately used within a regional range of approximately 27.5 km east–west of the reference location. Variations in dial readings are primarily influenced by elevation differences, the equation of time, solar declination, and local geographical coordinates.

Overall, the *Shollu* Dial Lokal provides an accessible, low-technology alternative for communities with limited access to digital tools, electricity, or internet connectivity. Its accuracy, simplicity, and ability to accommodate local astronomical parameters demonstrate its potential as a practical instrument for determining prayer times in diverse regional contexts.

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